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Profile of ecological practicum, logical thinking, and system thinking pre-service biology teacher

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ABSTRACT

Ecology is a complex system, so it requires thinking skills to understand it. One of the skills that can be trained in ecological practicum lectures is systems thinking skills. Ecology practicum has the potential and strategic role in preparing quality students to face the era of industrialization and globalization. This potential will be realized if practicum activities can equip students with the ability to think logically, think creatively, think critically, and think systems, which ends up being able to solve integrated problems. To design an ecology practicum program that can train systems thinking skills, it is necessary to know the existing forms of ecological practicum implementation, students' systems thinking skills, and their logical thinking skills. This study aims to obtain information on the description of these three things so that it becomes the basis for developing a better practicum program. and adaptive to changes and developments of the times. This research is in the form of field research, namely research whose object is about the symptoms or events that occur in the subject group. 18 third-level students and 39 fourth-level students were selected as research subjects. Limited interviews were conducted with practicum assistants and course lecturers. The instrument used consisted of a logical thinking ability test, systems thinking scale, systems thinking test, and interview guidelines. The results of the study show practicum activities only practice the skills of collecting, processing, and analyzing ecological data. Students' logical thinking ability is in a "good" category, especially at the level of combinatorial reasoning. Students' systems thinking ability is low, especially forest thinking skills.

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INTRODUCTION

Learning in higher education not only provides learning about knowledge but is also a process of providing learning experiences to gain knowledge (how to know). Therefore, laboratory or practical work activities are essential activities and become an integral part of science learning (Millar & Abrahams, 2009). Students have the opportunity to make direct observations and explore and understand the object of the biological study so that practicum activities can also combine hands-on with thought processes.

In the curriculum structure of biology education, the ecological practicum course is charged with the learning outcomes of graduates, which are grouped into four learning outcomes, namely attitudes, general skills, special skills, and mastery of knowledge. In carrying out the lectures, the ecology practicum utilizes indoor and outdoor activities. The laboratory is one of the educational facilities that can be used as a place to practice the science process. Students can make contact with the object being studied directly either through observation or by conducting experiments. The laboratory is an important and main part of the educational process, meaning that students individually or in groups with the guidance of lecturers learn to practice actively using all their five senses, brains, and energies in solving various problems, then discussing the results of their studies to gain knowledge.

Ecology is a complex system, so it requires thinking skills to understand it. One of the skills that can be trained in ecological practicum lectures is systems thinking skills. Partnership for 21st-century skills creates a competency framework that explains that systems thinking is a part of critical thinking skills developed. The Partnership for 21st-century skills defines critical thinking as effective reasoning (using a variety of reasoning), systems thinking (analyzing interacting components to produce a whole in a complex system), making judgments and decisions (evaluating effectively and evidence and arguments), and problem-solving (identifying and asking important questions that seek appropriate solutions from multiple points of view)(National Education Association, 2012; Ventura et al., 2017).

Ecology practicum has the potential and strategic role in preparing quality students to face the era of industrialization and globalization. This potential will be realized if practicum activities can provide students with the ability to think logically, think creatively, solve problems, think critically, think about systems, master technology and be adaptive to changes and developments of the times. Systems thinking skills (STS) are tools for the scientific process, especially in the analysis and synthesis process (Boersma et al., 2011). Analytical and synthesis skills are part of higher-order thinking (Gupta & Mishra, 2021; Jarvis & Baloyi, 2020; Yee et al., 2015).

The provision of STS in the ecology practicum is to provide understanding to prospective teacher students about the complexity of the environment around them. This biological complexity can be manifested in various levels of the organization of life from the molecular level to the ecosystem (Boersma et al., 2011; Rowan, 2012). STS can use general system theory (General System Theory/GST), cybernetics, and system dynamics. General system theory includes the ability to identify the components in the system, explain the function of each component, analyze the relationship between each component, analyze the relationship between the system and other systems, and analyze the energy cycle. Cybernetics is concerned with the balance of substances between system boundaries (homeostasis). Dynamic systems are systems that can organize themselves, are open, and produce interactions between components (Aguayo & Eames, 2017; Ateskan & Lane, 2018; Boersma et al., 2011; Fuertes-Camacho et al., 2019; Gómez Martín et al., 2020; Lee et al., 2019). Because systems thinking is a high-level thinking ability, to train it, it is necessary to have logical thinking skills as a basis that students must possess.

The ability to think logically is used as a characteristic of someone who reaches the level of formal reasoning in logical reasoning. Lay, (2009) suggests that the low logical thinking ability of students can be related to the current science education system. The science education system is generally only product-oriented in the form of test scores so that students do not use their thinking skills. Science learning is carried out only to fulfill the material requirements set out in the syllabus and the allocation of learning without allowing students to conduct inquiries (investigations) to train students thinking skills. There are five formal intellectual reasoning students in thinking, namely the ability to think proportionally, controlling variables, probability, correlation, and combinatorial (Tobin & Capie, 1981). These five formal reasoning are divided into three categories, namely, the ability to think concretely, transitional, and formal reasoning.

Based on initial observations, so far, the ecological practicum program has not been running optimally. Practical activities that are usually carried out are still in the form of verificative practicum activities (proving). The lack of variety of ecological practicum activities also results in students not being able to explore studies in-depth and use them to solve practical problems in their daily lives. This incomplete information will cause students to have difficulty constructing knowledge so that student learning outcomes are less than optimal (Tatar, 2012). To be able to utilize ecological knowledge in everyday life, students must be able to understand the ecological complexities that can be manifested in various levels of the organization of life from the molecular level to the ecosystem. So we need a practicum program that is comprehensive and able to train thinking skills, such as systems thinking, which ends up being able to solve integrated problems. To design an ecology practicum program that can train systems thinking skills, it is necessary to know the existing forms of ecological practicum implementation, students' systems thinking skills, and their logical thinking skills. This study aims to obtain information on the description of these three things so that it becomes the basis for developing a better practicum program.

METHODS

Research Design

This type of research is field research, namely research whose object is about the symptoms or events that occur in the subject group. So this research can also be called a case study or case study with a qualitative descriptive approach.

Subject

The research subjects were 18 third-level students and 39 fourth-level students, two practicum assistants, and one ecology practicum lecturer. All students have finished contracting the ecology practicum course. In addition, an analysis of the contents of the ecology curriculum instructions was carried out on five ecology practicum instructions from five different universities, both public and private.

Instrument

1. Test of logical thinking ability (TOLT)
   TOLT for prospective biology teacher students was modified and translated from TOLT (Tobin & Capie, 1981). This test consists of 10 items covering five types of logical thinking skills, namely proportional reasoning, variable control, probability reasoning, correlational reasoning, and combinatorial reasoning. TOLT was developed in the form of two-tier multiple-choice (reasoned multiple choice), except for combinatorial reasoning, respondents were asked to write down various possible combinations of several variables.
2. Systems Thinking Scale
   Consists of 20 statements that must be answered by students with four options, namely never, rarely, often, and always. The focus of this system thinking scale is on the system interdependence indicator developed by Moore et al., (2011).
3. System Thinking Test
   Test to measure systems thinking skills in the form of a description test based on the classification of systems thinking presented by Dorani et al., (2015). The classification consists of six complementary skills, namely Dynamic Thinking, System as Cause Thinking, Cause-Effect Thinking, Forest Thinking, Closed-Loop Thinking, and Stock and Flow Thinking.
4. Interview Guidelines
   Interviews were conducted in lecturers' and assistants' practices. The main questions for lecturers focus on the implementation of practicum, practicum topics, and skills that are trained in practicum activities. The questions for the assistant focus on the implementation of the practicum, the relationship with the supporting lecturer, the practicum recruitment process, and the assessment of the practicum instructions.

Procedures

The steps taken can be divided into three stages, namely the pre-research stage, the implementation stage, and the post-research stage. The details of the activities carried out at each stage are as follows:

1. Pre-research stage
   a. Determination of the class that will be the subject of the field study.
   b. Develop field study instruments, such as compiling RPS analysis formats and practical instructions, reviewing logical thinking test instruments, systems thinking scales, systems thinking skills tests, and compiling interview guidelines.
2. Implementation stage
   Data collection is based on problem identification, including:
   a. Observation of lecture support facilities, such as laboratories and other supporting facilities
   b. Collecting process documents for ecological practicum lectures such as RPS and practical instructions. Then analyzed.
   c. Measuring logical thinking ability, systems thinking scale, and systems thinking skills.
   d. Interviewing practicum assistants and lecturers in ecology practicum courses to find out the implementation of ecology practicum learning that has been carried out so far.
3. The final stage
   a. Processing and analyzing research data.
   b. Development of theory based on the data obtained.
   c. Preparation of reports.
   d.

Data Analysis Techniques

Data processing is carried out based on each data obtained from measurements and field notes, reduced, described, analyzed, and then interpreted. Data analysis procedureses for problems are more focused on efforts to explore facts as they are (natural setting), with an in-depth analysis technique (Verstegen).

RESULTS AND DISCUSSION

Description of Ecology Practicum Course

The Ecology Practicum Course is a mandatory course that must be followed by prospective teacher students in the Biology Education Study Program, Muhammadiyah University of Sukabumi. This Ecology Practicum course is offered in the sixth semester with a weight of two credits.. This Ecology Practicum course is offered in the sixth semester with a weight of two credits. In the curriculum structure of the study program, this ecology practicum course is separate from the ecological theory course, and both are offered in the same semester. The completeness of this ecology practicum course is determined by pretest and or post-test assessments during practicum activities, practicum reports, midterm exams, field lectures, end-of-semester exams, and attendance during practicum. There are 12 program learning outcomes (PLO) that are charged to the ecology practicum course. From the 12 PLO, they are elaborated into four-course learning outcomes (CLO) for the ecological practicum.

Table 1
CLO of Ecology Practicum Course

	Course Learning Outcomes
CLO 1	Students can analyze the fact that there are interrelationships between living things and their environment to understand the philosophy, concepts, principles, and procedures in ecology based on Al-Islamic values
CLO 2	Students can work independently, quality and measurable to master the methods and techniques in ecology
CLO 3	Students can apply critical, logical, and analytical thinking to master the skills of collecting, processing, and analyzing ecological data
CLO 4	Students can analyze every ecological problem to master the skills of solving ecological problems and internalizing them in values, norms, and ethics

Further analysis is carried out on the ecological practicum guidelines that have been used so far. The analysis is focused on the topic or practicum chapter provided in the practicum manual. To make a comparison, the ecological practicum manuals analyzed also include some ecology practicum instructions from four different universities. The results of the analysis are presented in table 2 below.

The results of the analysis of the Semester Lesson Plans show that the learning outcomes of the ecology practicum course cannot be fully accommodated by the practicum activities offered. For example, CLO-3 reads "Students can apply critical, logical, and analytical thinking to master the skills of collecting, processing, and analyzing ecological data" or CLO-4 reads "students can analyze every ecological problem to master the skills of solving ecological problems and internalize them in value. , norms and ethics", are not fully reflected in the activities offered in the practicum instructions. The practicum instructions provided only train the skills of collecting, processing, and analyzing ecological data, but have not yet trained critical, logical, and analytical thinking in solving ecological problems such as the demands on CLO.

Further analysis is carried out on the ecological practicum guidelines that have been used so far. The analysis is focused on the topic or practicum chapter provided in the practicum manual. In order to make a comparison, the ecological practicum manuals analyzed also include some ecology practicum instructions from four different universities. So the results of the analysis are presented in Table 2.

Table 2
Comparison of Ecology practicum guidelines at five different universities

Elements in Practicum Manual		Univ-A	Univ -B	Univ -C	Univ -D	Univ -E
Cover		Available	Available	Available	not available	Available
Identity Sheet		Avail able	not available	not available	not available	not available
Preface		Available	Available	Available	not available	Available
Work rules Laboratory		Available	not available	not available	not available	not available
Table of contents		not available	Available	Available	not available	not available
List of Figures and Tables		not available	not available	not available	not available	not available
A number of Practicum Chapters		8	13	9	8	10
Title of Practicum Chapter	1	Introduction of Tools	Introduction of Tools	Population Interaction	Analysis of Land Habitats	Introduction of Environmental Factors and Instruments Measurement
	2	Micro-climate Observation	Limiting Factors in Terrestrial Ecosystems	Succession	Population Analysis	Animal Response
	3	Lebistes preference for temperature	Intraspecific and Interspecific Competition	Minimum Area and Minimum Number of Squares	Interaction of Plants with Insects	Feed Preference *Ephilacna Sp.*
	4	Taxis Movement of Earthworms	Measuring Populations	Community Diversity and Dispersal Patterns of Individuals in a Population	Competition	Population Estimation Methods
	5	Pedosphere	Interspecific Association	Estimation of Insect Population Abundance	Presence of Dung Beetle	Soil Animal Sampling Method
	6	Capture-Mark-Release-Recapture (CMRR)	Basic Techniques for Measuring Tree Parameters	Preference of Organisms to Temperature	Plant Succession	Population Growth Rate
	7	vegetation analysis	Lichenes Biodiversity	vegetation analysis	Animal Succession	Macrozoobenthos Community Structure in River

Elements in Practicum Manual		Univ-A	Univ -B	Univ -C	Univ -D	Univ -E
						Ecosystems
	8	Benthos	Terrestrial and Aquatic Ecosystems	Observation of Herpetofauna (Reptiles and Frogs/Amphibians)	Plant Distribution	Arboreal Mammal Population Estimation (Line Transect Method)
	9	-	Cryptogame Diversity Analysis	Daily Behavior and Circular Distance (*Achatina fulica*)	-	Daily Activities of Snails (*Achatina Sp.*)
	10	-	Minimum Area and Minimum Sum of Squares	-	-	Plankton Daily Fluctuation
	11	-	Macro-invertebrates (Benthos)	-	-	-
	12	-	Plankton	-	-	-
	13	-	Functional Diversity Analysis	-	-	-
Systematics in each chapter	1	Objective	Brief Theory	Introduction	Objective	Practicum Objective
	2	Introduction	Objective	Objective	Theory	Tools and Materials
	3	Tools and Materials	Tools and Materials	Tools and Materials	Procedures	Procedures
	4	Procedures	Procedures	Procedures	-	-
	5	Observation Sheet	Brief Discussion	Observation Result	-	-
	6	Tentative Conclusions	Conclusions	-	-	-
Practical Guide presents project-based learning		No	No	No	No	No
Practical Instructions present case study learning		No	No	No	Yes	No
Practical Instructions present problem-based learning		No	No	No	No	No
Practicum Instructions practice system thinking skills		No	No	No	No	No

Table 2 shows that most of the analyzed practicum instructions did not have complete practical instructions such as covers, practicum instructions identity sheets, introductions, work procedures in the laboratory, table of contents, list of figures and list of tables. Furthermore, the number of chapters or practicum topics from these five universities varies, ranging from 8 to 13 practicum chapters. The results of the analysis show that there are quite a lot of the same practicum topics even though the names are slightly different. The practicum topics include the introduction of tools and measurement of environmental factors/microclimate observations, preference of organisms to abiotic factors, measuring or estimating populations, vegetation analysis, analysis of diversity and distribution of living things, daily behavior, and orbital distances of living things, population interactions, succession. , community structure, and macrozoobenthos. Practical topics that are only found on one or two campuses include pedosphere practicum and interspecific associations.

The problem that appears is not only the difference in the number of practicum topics but also the order of practicum topics from the beginning to the end. Ecology practicum of course must pay attention to the order of material from simple to complex or take into account the prerequisites between topics to be practiced. For example, all ecological practicums should begin with an introduction to the tools that will be used in the practicum. Ecological tools require special skills in using so that the data obtained are precise and accurate. Furthermore, the practicum begins to move to the level of the individual, community, population, interaction, and so on. The choice of practicum topics should also take into account the potential and problems of the area as a source of ecological learning so that the practicum is more meaningful.

The results of the analysis of the ecological practicum manuals also show that none of the practicum manuals trains inquiry, critical thinking, systems thinking, problem-solving, or in the form of projects. The existing practicums generally only train the skills of collecting, processing, and analyzing ecological data. This finding is reinforced by the results of interviews with lecturers who state that there is limited knowledge related to how to train students' thinking skills, for example, systems thinking which are closely related to the topic of ecology as a system. Even though laboratory or practical work activities are essential activities and become an integral part of science learning (Millar & Abrahams, 2009). Students have the opportunity to make direct observations and explore and understand the object of the biological study, so that practicum activities can also combine hands-on activities with thought processes.

Furthermore, in general, the practical instructions used are still in the form of a recipe book and have not fully honed students' thinking skills. This results in a lack of meaningful practical experience for students, so students have difficulty understanding ecological materials. Verificatory practicum causes students to get bored quickly so it can reduce students' learning motivation to explore and elaborate on the material. The verificative learning experience also does not train students' thinking process skills, so students are less challenged to carry out practical activities carried out. With the verification practicum method, although students are involved hand-on and mind-on meaning is not felt by students.

Logic Thinking Ability

The ability to think logically is obtained through a logical thinking ability test (Test of Logic Thinking) developed by Tobin & Cape (1981). This instrument is able to measure students' formal reasoning, which includes all reasoning. In addition, the test can classify students' scientific reasoning categories which consist of concrete operations, transitional, and formal operations. The level of logical thinking ability possessed by prospective biology teacher students can be seen in Figure 1.

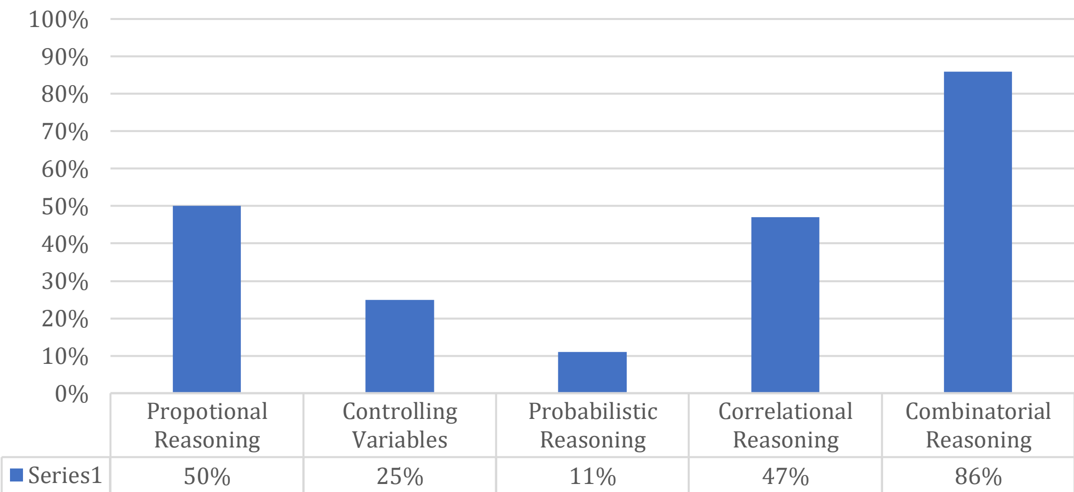

Figure 1. Percentage of Students' Logical Thinking Ability Level

Figure 1 shows the logical thinking skills possessed by students having different percentages at each level. Students obtained the highest level of logical thinking ability for combinatorial reasoning (86%) and the lowest for probability reasoning (11%). There are five formal intellectual reasoning students in thinking, namely the ability to think proportionally, controlling variables, probability, correlation, and combinatorial (Tobin & Capie, 1981). These five formal reasoning are divided into three categories, namely the ability to think concretely, transitional, and formal reasoning. The results of the measurement of logical thinking skills show that students have different percentages of logical thinking abilities at each level. Students achieve the highest level of logical thinking ability for the level of combinatorial reasoning (86%) and the lowest level of probability reasoning (11%). These findings are in line with the results of research by Lay (2009) which shows the results of the lowest probability reasoning score, but the highest score on combinatorial reasoning. Combinatorial reasoning is the process of analyzing problems combinatorially using various facts from cause-and-effect relationships or using certain arrangements on objects to form units that meet certain criteria (Lawson, 1978). A high level of combinatorial reasoning is a good provision for students to practice systems thinking skills.

The development of logical thinking skills is a top priority in education science. The ability to think logically has a fundamental role in student academic achievement and in constructing concepts. Students with a high level of logical thinking ability can change their alternative conceptions more easily (Oliva, 2003). Proportional reasoning is quite important in the quantitative aspects of chemistry, especially for understanding the derivation and use of a large number of functional relationships in chemistry, such as the development and interpretation of tabulated and graphed data. Correlational reasoning plays a very important role in the formulation of hypotheses and interpretation of data that needs to consider the relationship between variables. Controlling variables is important in planning, implementation, and interpretation. Data interpretation of findings, observations, or experiments often requires probabilistic reasoning. Lastly, combinatorial reasoning occurs in the formulation of alternative hypotheses to test the effects of the selected variables.

The results of the logical thinking test also produce data for the category of student scientific reasoning. Students' scientific reasoning is grouped into concrete operational, transitional, and formal operational categories which are presented in Figure 2.

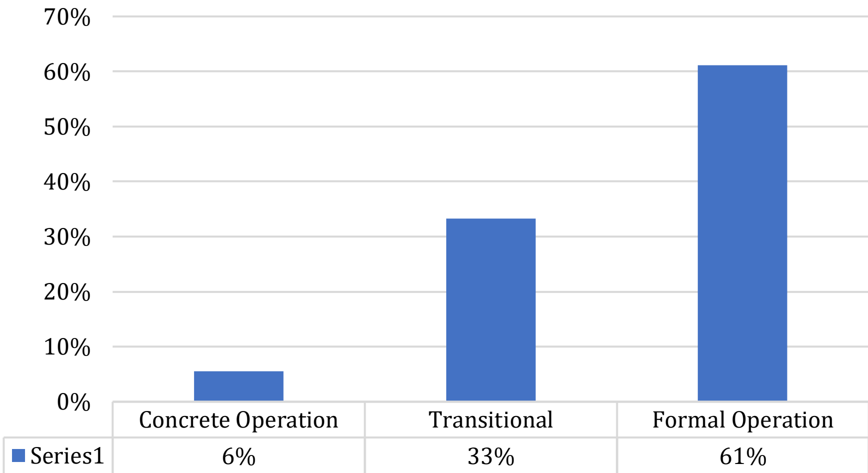

Figure 2. Percentage of Student Scientific Reasoning Category

Figure 2 shows the data for the student's scientific reasoning category. Students' scientific reasoning is grouped into concrete operational, transitional, and formal operational categories. The measurement results show that most students enter the transitional level of reasoning (33%) and formal operations (61%). However, there are still around 6% of students who fall into the category of concrete operational reasoning.

Someone whose cognitive development has reached the level of formal operation will find it easier to solve problems in the learning process. This is because he has been able to use his mind to solve various concrete and abstract problems logically and systematically. It is believed that formal reasoning that is characteristic of the formal operational level is very important for a child to be successful in science and vocational fields.

Several other researchers stated that students' formal reasoning ability is an indicator of student success in mathematics and science (Cantu & Herron, 1978). This formal thinking ability is needed by students in various learning activities that require students to be active in thinking, especially in solving the problems given. Knowledge of students' formal reasoning in learning makes it very important to be able to see students' abilities in learning (Rakhmawan & Vitasari, 2016).

Scale and System Thinking Ability

The scale of system thinking consists of 20 statement items that have been answered by students with four options, namely never, rarely, often, and always. The focus of this systems thinking scale is on indicators of system interdependence developed by Moore et al., (2011). Student answers are presented in Table 3.

Tabel 3.
Biology Pre-service teacher Student System Thinking Scale

No	When I want to make improvements...	Percentage of Answers (%)
1	I ask the views of all my friends in the group about the situation.	78.21
2	I look for the root of the event to determine the cause of the problem	83.33
3	I think it is very important to understand how the chain of events occurs	80.77
4	I involve members of my group in finding solutions	83.33
5	I think repeating patterns are more important than one particular event	65.13
6	I consider the problem as a series of interrelated problems	69.87
7	I consider cause and effect in a situation	87.18
8	I consider the relationship between group members	77.56
9	I think that the system continues to change	76.92
10	I propose a solution that affects the class environment, not a specific individual	68.59
11	I remember that the proposed change could affect the whole system	76.92
12	I think it takes more than one or two people to succeed	77.56
13	I always remember the group's mission and goals	78.85
14	I think small changes can produce important results	91.67
15	I consider many changes affect one another	84.62
16	I think that different group members might be affected by the improvement	71.15
17	I try strategies that do not depend on people's memories	62.82
18	I realize system problems are affected by past events	60.26
19	I consider history and culture	58.97
20	I assume that the same action can have different effects over time, depending on the state of the system	80.77
	Average	**75.72**

The systems thinking scale is intended to measure how often students are involved in activities that are systems thinking activities. The system thinking scale is categorized into four groups, namely never (0-25%), rarely (26-50%), often (51-75%), and always (76-100%). The measurement results show that biology education students often (75.72%) perform systems thinking activities.

Systems thinking skills were measured using a description test based on the classification of systems thinking presented by (Dorani et al., 2015). The classification consists of six complementary skills, namely Dynamic Thinking, System-as-Cause Thinking, Cause-Effect Thinking, Forest Thinking, Closed-Loop Thinking, and Stock and Flow Thinking. The results of the measurement of systems thinking are presented in Figure 3.

In general, students' systems thinking skills in biology education are still low with an average score of 54.74. The highest value is on the closed loop thinking indicator of 57.82, while the lowest value is on the forest thinking/holistic thinking indicator (Forest Thinking) of 49.87. Systems thinking scale and systems thinking skills test are given to students of biology education respectively. The results of the measurement of the systems thinking scale show that students *often* (75.72%) perform systems thinking activities. However, the results of the measurement of this scale are dubious because they are not in line with the results of the system thinking skills test whose average results are still low (54.74). Systems thinking skills were measured using a description test based on the classification of systems thinking presented by (Dorani et al., 2015). The classification consists of six complementary skills, namely dynamic Thinking, System-as-Cause Thinking, Cause-Effect Thinking, Forest Thinking/Holistic Thinking (Forest Thinking), Closed-Loop Thinking, and stock and Flow Thinking. The test results show that the highest score is on the closed-loop thinking indicator 57.82, while the lowest value of the holistic thinking/holistic thinking indicator (Forest Thinking) is 49.87.

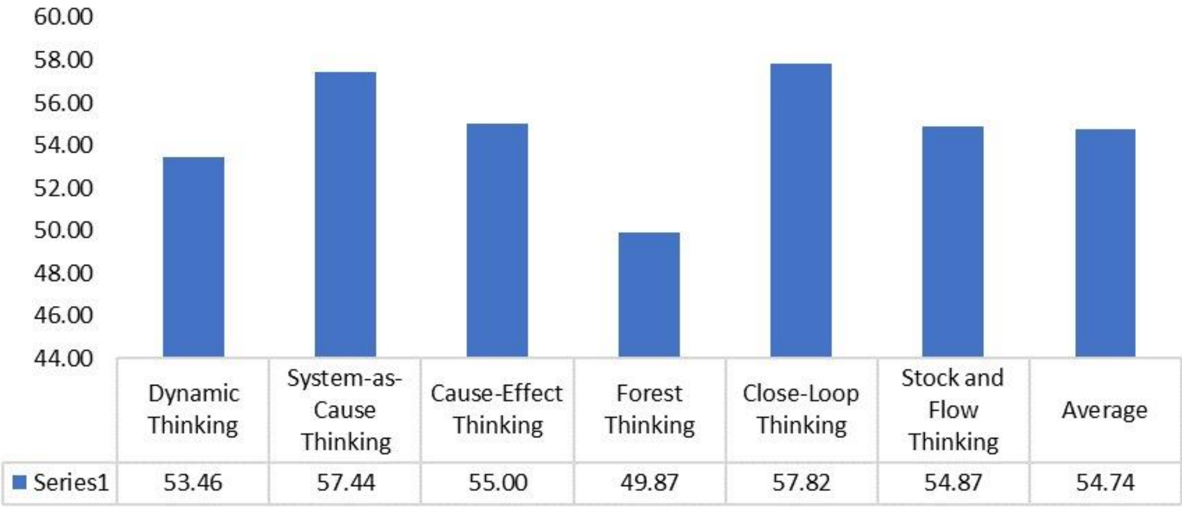

Figure 3. System Thinking Scores Per Indicator

Forest Thinking is the ability to see the big picture and how its parts relate and interact. By looking at the system we can see how relationships that may extend far in space or time can contribute to smaller local outcomes (Richmond, 2000). Forest thinking will be produced by a system thinking training process that is not short. Repeated experiences will make a person have forest thinking.

CONCLUSION

Based on the analysis of the results of the field study, it was found that the existing practicum activities generally only trained the skills of collecting, processing, and analyzing ecological data. The contents of the practicum instructions have not trained thinking skills such as critical thinking, systems thinking, or problem-solving. The practical instructions used are still in the form of a recipe book so the practicum is only verification. The students' logical thinking ability is classified as good, especially at the level of combinatorial reasoning. In addition, most of the students' reasoning categories are in the formal operational category. The students' system thinking ability is low, especially on the forest/holistic thinking ability indicator. From these findings, it can be concluded that there is still an opportunity to develop an ecological practicum guide that can train thinking skills in higher education.

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